Desktop-Gluey: Augmenting Desktop Environments with Wearable Devices

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Figure 1. Copying a sketch from a desktop screen and pasting it to a tablet with Gluey [5]

Abstract
Upcoming consumer-ready head-worn displays (HWDs) can play a central role in unifying the interaction experience in Distributed display environments (DDEs). We recently implemented Gluey, a HWD system that 'glues' together the input mechanisms across a display ecosystem to facilitate content migration and seamless interaction across multiple, co-located devices. Gluey can minimize device switching costs, opening new possibilities and scenarios for multi-device interaction. In this paper, we propose Desktop-Gluey, a system to augment situated desktop environments, allowing users to extend the physical displays in their environment, organize information in spatial layouts, and 'carry' desktop content with them. We extend this metaphor beyond the desktop to provide 'anywhere and anytime' support for mobile and collaborative interactions.

Author Keywords
Head-Worn Display, distributed displays, multi-display environments, input redirection, content migration.

Introduction
A new generation of lightweight, see-through head-worn displays (hereafter referred to as 'HWDs') is emerging for general purpose use (e.g. Google Glass,

Meta, Microsoft HoloLens). These wearable devices will soon co-exist within a larger environment of distributed displays (i.e. desktop monitors, tablets, smartphones) we depend on for daily information tasks. However, distributed display environments (DDEs) are commonly afflicted by device switching and data transfer costs.

To this end we implemented Gluey [5], a system that acts as a 'glue' to facilitate seamless information flow and input redirection across multiple devices (Figure 1). The HWD embedded cameras and spatial sensors allow Gluey to discover and maintain a spatial model of the relative positions of various devices, which can be used to facilitate cross-device interactions. Gluey allows users to move content across devices and to freely interact with other displays using any available input device.

We envision that Gluey will soon become the "new desktop environment", in which, with only a mouse and a keyboard, a user can create a desktop anywhere and anytime by using available mobile or wearable devices.

Gluey

Gluey [5] exploits the unique features of HWDs such as *view-fixed displays*, *cameras* and inclusion of *spatial sensors. From these sensors* we can determine a user's head position in relation to the environment and from the camera data, we can reveal what the user is viewing. For example by simply moving a smartphone into view of the HWD's camera, the user can link his desktop keyboard and the smartphone. Further, we can use the device's *view-fixed display* as an always-available 'canvas' for showing *visual feedback* about interactions. For example, this display can show a *visible clipboard* space to store *multiple data objects* in transit between copy/paste operations to multiple interleaved destinations. Gluey pairs input devices with displays to provide a unified interaction experience in the DDE: the Gluey user can use any input device, such as a keyboard, mouse, mobile touchscreen or mid-air finger gesture to control multiple displays.

We implemented Gluey on an Epson Moverio BT-100 head-worn display equipped with a Logitech C270 HD webcam. Our prototype tracks the position of surrounding devices with the marker-based ARToolkitPlus. We set the HWD background color to black to maintain display transparency. Each input device is associated with only one display at any time.

Desktop-Gluey Scenario

Our existing Gluey prototype illustrates how HWDs can leverage the interaction experience in DDEs. In our current work, we envision **Desktop-Gluey**, which extends beyond the physical displays in a desktop environment. In this novel concept, users can organize information in spatial layouts and carry desktop content anywhere. Here we illustrate the capabilities of Desktop-Gluey through the following usage scenario.

John, an architect, relies on numerous devices while switching between various spatial locations in his daily work: office, constructions, client's workplace, public transports and home. With Desktop-Gluey, John can seamlessly carry his virtual desktop with him, extending available displays (tablets, smartphones) and utilizing any available input device for interaction.

Extending Physical Displays

In a traditional desktop setup, Gluey can extend the physical displays with virtual windows, which can display additional contents (Figure 2). As device resolution and FoV continue to increase, these virtual windows can eventually replace the real monitors and reduce desktop clutter. The virtual windows can even have larger virtual 'footprints' than their physical counterparts. More interestingly, the user can carry such displays and use the desktops wherever needed.

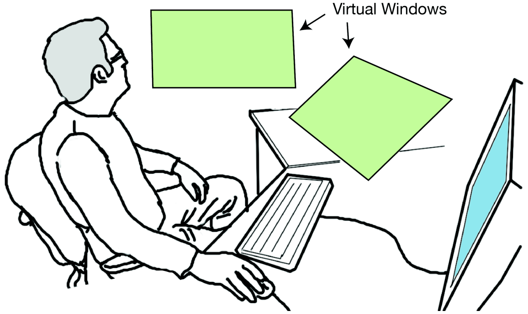

Figure 2. Extending physical displays with virtual windows.

Spatial Information Layouts
Using Desktop-Gluey, virtual content can be spread out beyond the boundaries of desktop screens in specific spatial arrangements (Figure 3), similar to the Personal Cockpit interface [1]. For instance, the user can always choose to place a calendar, email client, and a contact list in three different spatial locations, each endowed with specific semantic association to minimize the efforts in content relocation and window management. Of course, one aspect that needs further investigation concerns placing such windows ergonomically to allow the user to view them with great conform and striking a balance between display size, location and reachability to facilitate direct interaction with the displays.

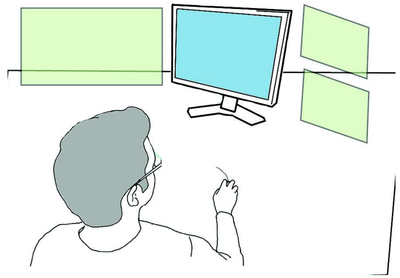

Figure 3. Spatial arrangement of virtual windows.

"Mobile" Desktop
With Desktop-Gluey, the physical desktop now becomes mobile. All the user needs is a keyboard and mouse. In situations where no input device is available, the user can employ any device with him/her, such as a tablet or a smartphone (Figure 4). Even if there is no personal device at hand, the user could still interact with Desktop-Gluey using on-body gestures (e.g. [4]).

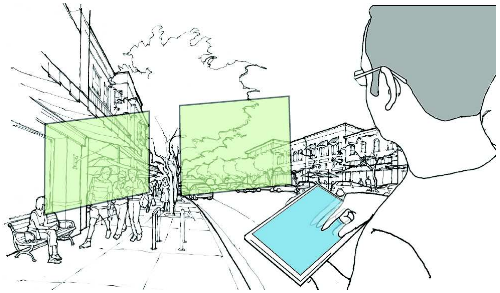

Figure 4. A mobile desktop allows the user to take their applications and content wherever they may go.

Collocated Desktops
Current desktop environment are meant to be used by a single user: collocated interaction can only take place around one person's desktop. As such, only one user can interact with the desktop with others having only

minor participation in any collaborative work. Desktop-Gluey could provide a unified collocated experience by allowing multiple users to interact with a single shared virtual desktop. For instance, a professor and a student working on a paper could share documents seamlessly by using virtual windows residing on the desk surface. Moreover, each user could interact with these documents using their own input devices (Figure 5).

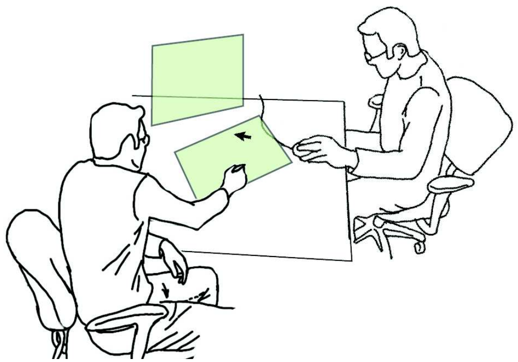

Figure 5. Collocated interaction around a virtual desktop.

The proximity [3] of the user can be used to define the spatial properties and the content of the collocated virtual windows. For instance, as a user exits from the public space (1.2m) to personal (0.45m), the virtual windows become smaller and display personal content.

In the same manner the f-formations, i.e. the relative body orientation among users [3], could be mapped to different spatial layouts of a virtual desktop [1]. For instance, when two users are facing each other (face-to-face), virtual windows could be placed on their side. When the users are facing the same direction (side-by-side), the windows could be situated in front of them. Finally, when the users are facing perpendicular to each other (corner-to-corner), the windows could be arranged in an 'L' layout (Figure 6). As such, windows would be oriented in the most optimal locations for both users to interact with content.

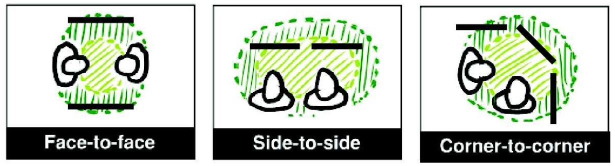

Figure 6. F-formations, modified from [3] to show corresponding spatial layouts for virtual desktop windows.

Conclusion

Our proposal explores how to augment current desktop environments using wearable ecosystems. We propose Desktop-Gluey to expand beyond physical desktop displays, to organize information in spatial layouts, and to support mobility and collaboration.

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